COMPUTER NETWORKS

INTRODUCTION

- **Computer networks** have had revolutionary impact
  - Education, research, medicine, and more benefits
  - Worldwide communications
  - Helps to equalize access to information.

- Possibly a vehicle for spreading misinformation
  - Fake news
  - Rumors
  - Falsehoods

COMPUTER NETWORKS

- **Computer network** is made up of computing devices (**nodes / hosts**) and interconnections for the purpose of sharing the information and resources.

- Networks may be wired or wireless.

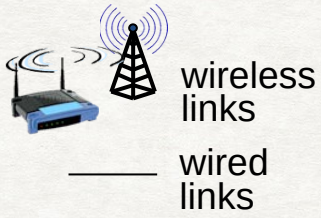
- Wired networks
  - **Dial-up**
  - **Broadband** (**cable modems** and **DSL**)

- Wireless networks
  - **Wifi/Cellular**

THE INTERNET

End Systems (hosts)

billions of connected devices running network apps



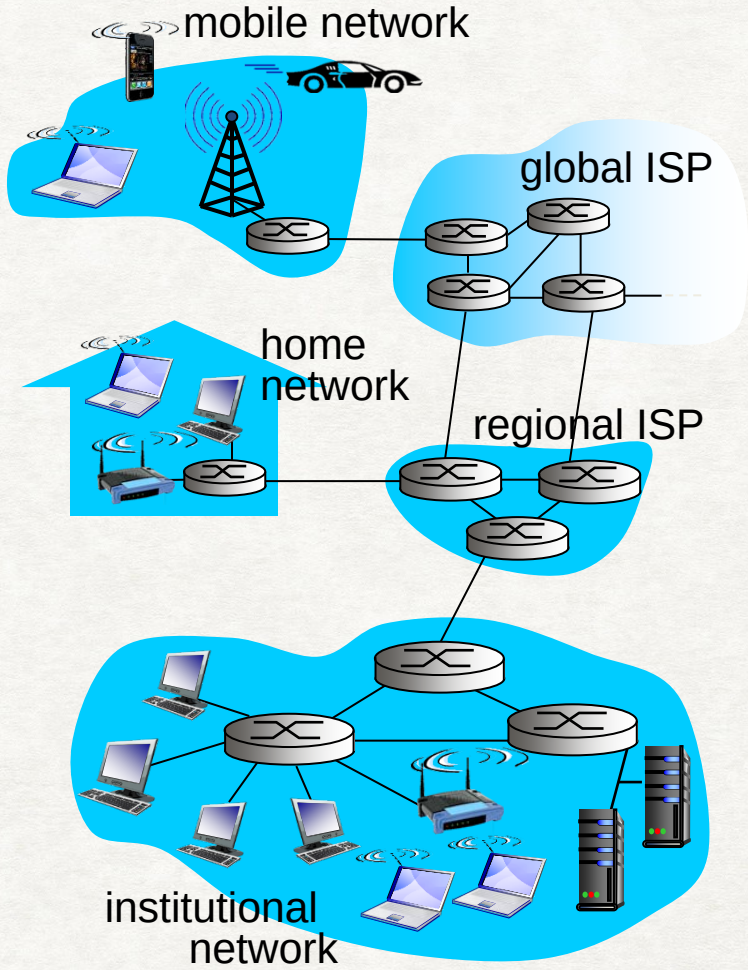
communication links

fiber, copper, radio, satellite

transmission rate: bandwidth

Packet switches: forward packets (chunks of data)

routers and switches



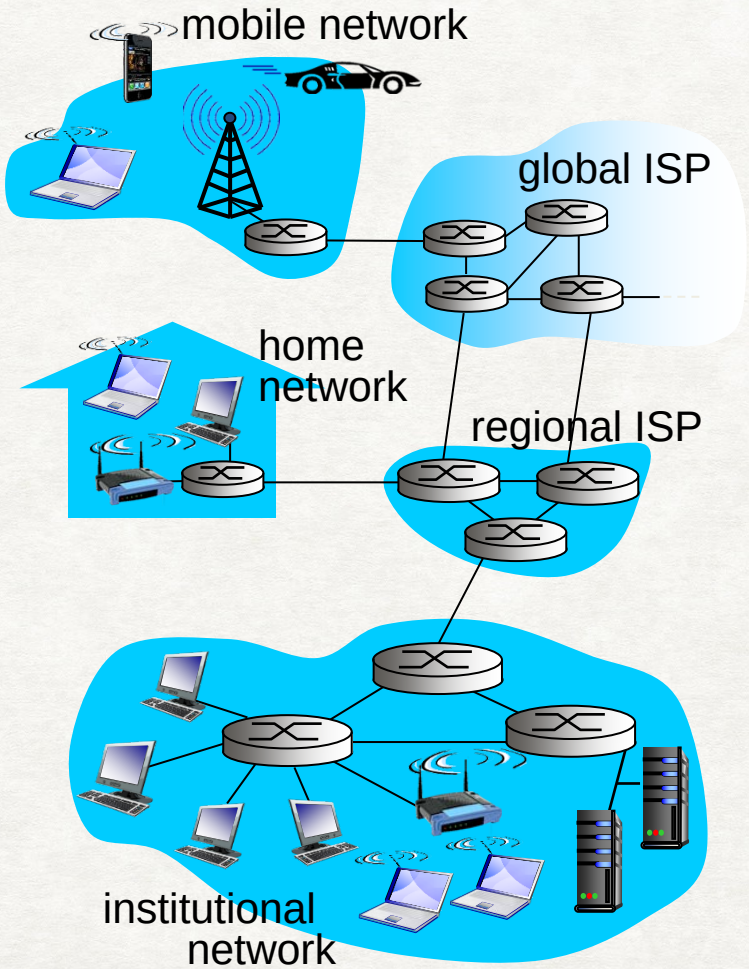
Reference : *Computer Networking: A Top Down Approach by Kurose & Ross*

THE INTERNET

1. **Network Edge:**
   - hosts: clients and servers
   - servers often in data centers

2. **Network Core:**
   - interconnected routers
   - network of networks

3. **Access networks:**
   - connect end systems to edge router
   - wired or wireless links



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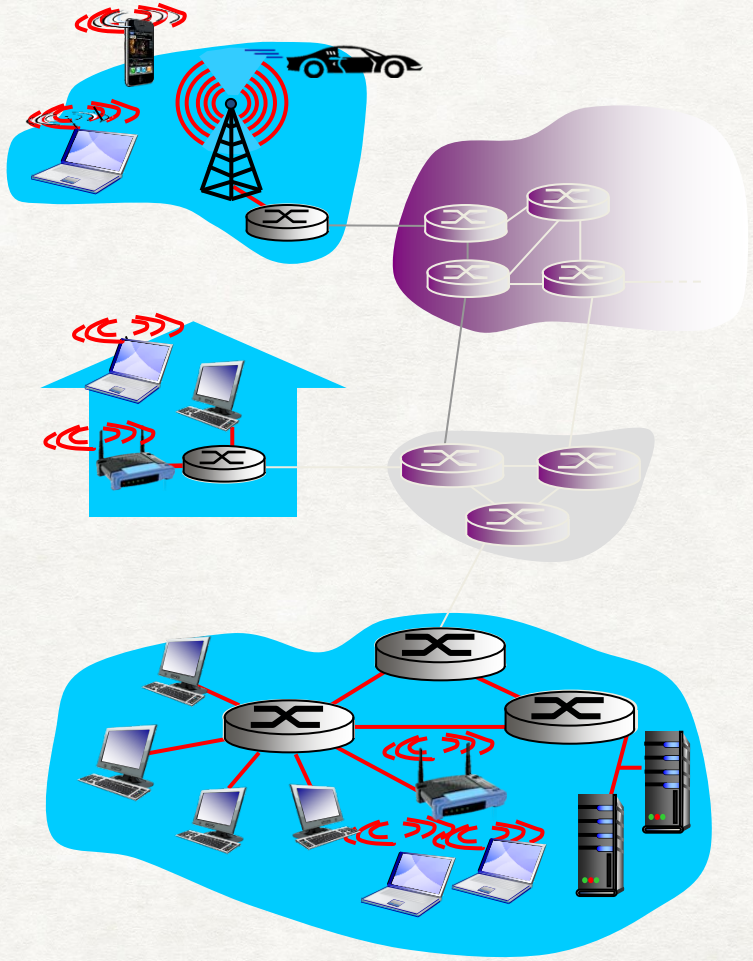
Access networks

1. Residential access networks
2. Institutional access networks (school, company)
3. Mobile access networks



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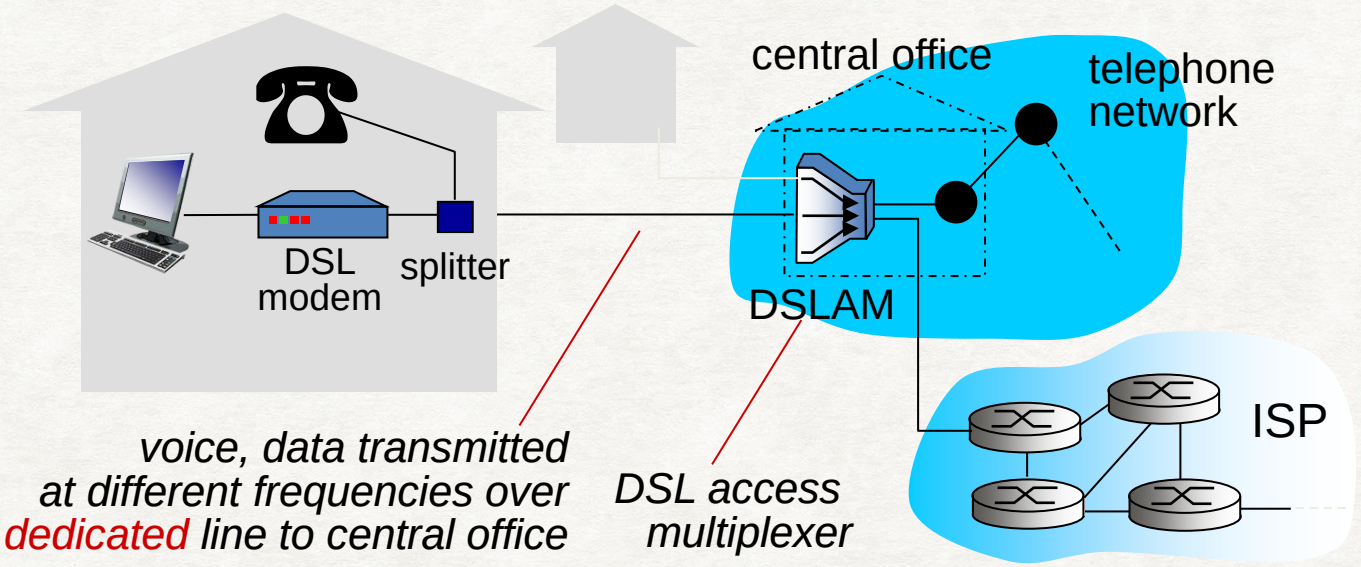
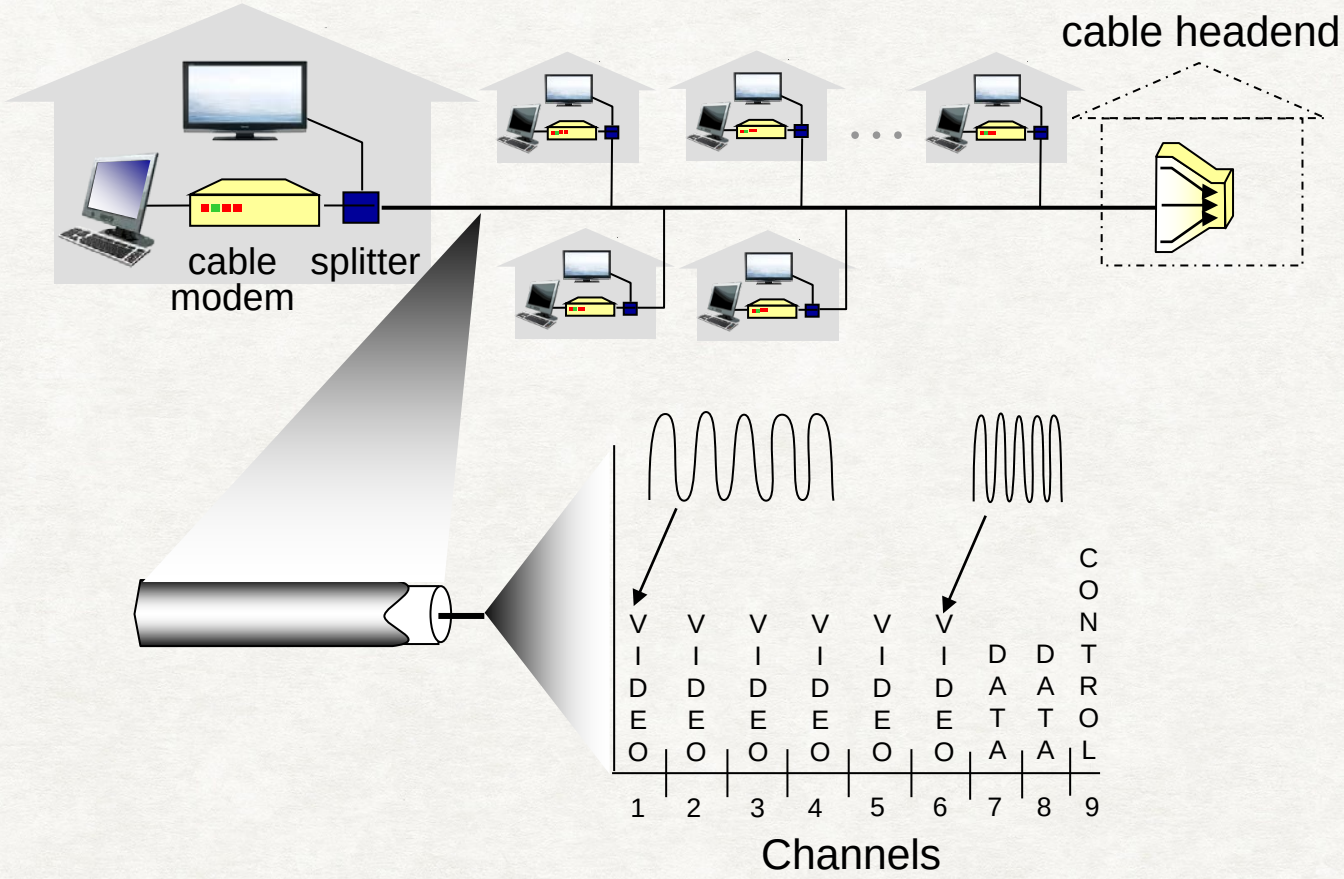
Access net: Digital Subscriber Line (ADSL, VDSL, xDSL)



- Uses *existing* telephone line to central office DSLAM
  - data over DSL phone line goes to Internet
  - voice over DSL phone line goes to telephone net
- < 2.5 Mbps upstream transmission rate (typically < 1 Mbps)
- < 24 Mbps downstream transmission rate (typically < 10 Mbps).
- Distances up to a few km from telephone exchange to home
- Provides two-thirds of broadband access in New Zealand.

Reference : *Computer Networking: A Top Down Approach by Kurose & Ross*

Access net: Cable Network



frequency division multiplexing: different channels transmitted in different frequency bands

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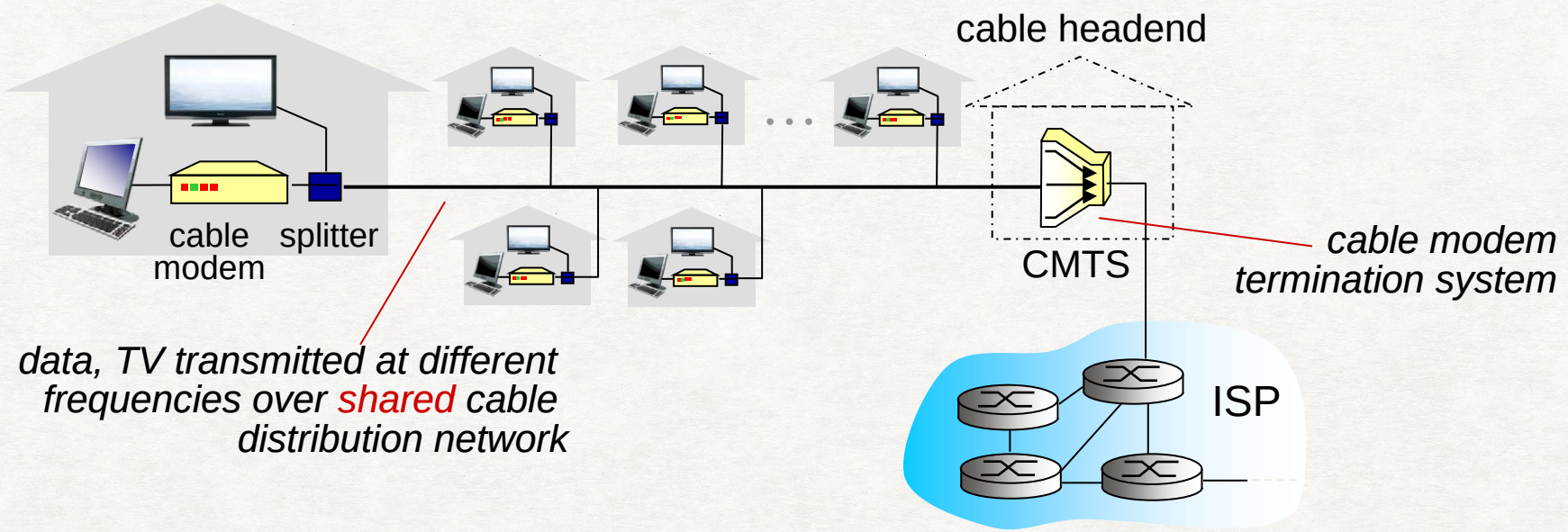
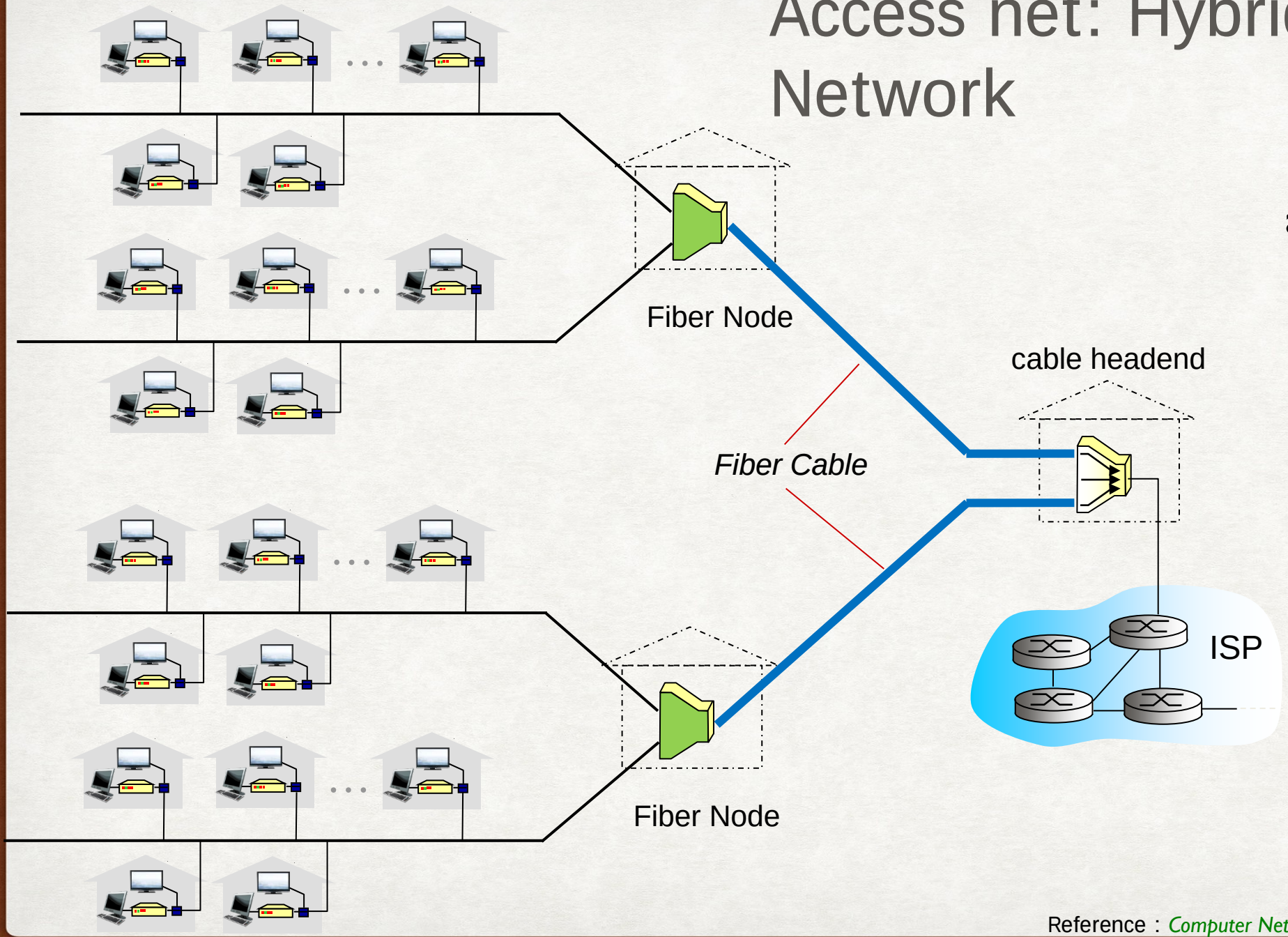
Access net: Cable Network



- Cable attaches homes to ISP router
  - homes share access network to cable headend
    - unlike DSL, which has dedicated access to central office
  - asymmetric: up to 30Mbps downstream transmission rate, 2 Mbps upstream transmission rate

Reference : *Computer Networking: A Top Down Approach by Kurose & Ross*

Access net: Hybrid Fiber Cable Network



Network of cable, fiber attaches homes to ISP router

Fiber optics connect the cable head end to neighborhood-level junctions, from which traditional coaxial cable is then used to reach individual houses and apartments.

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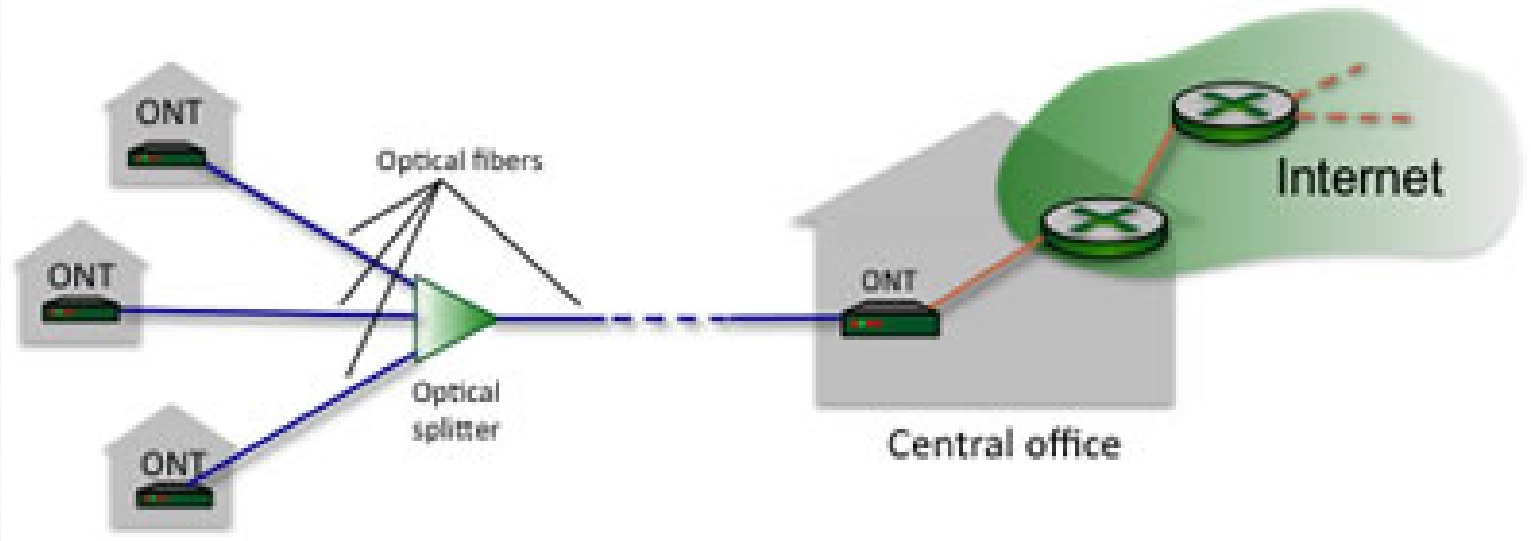
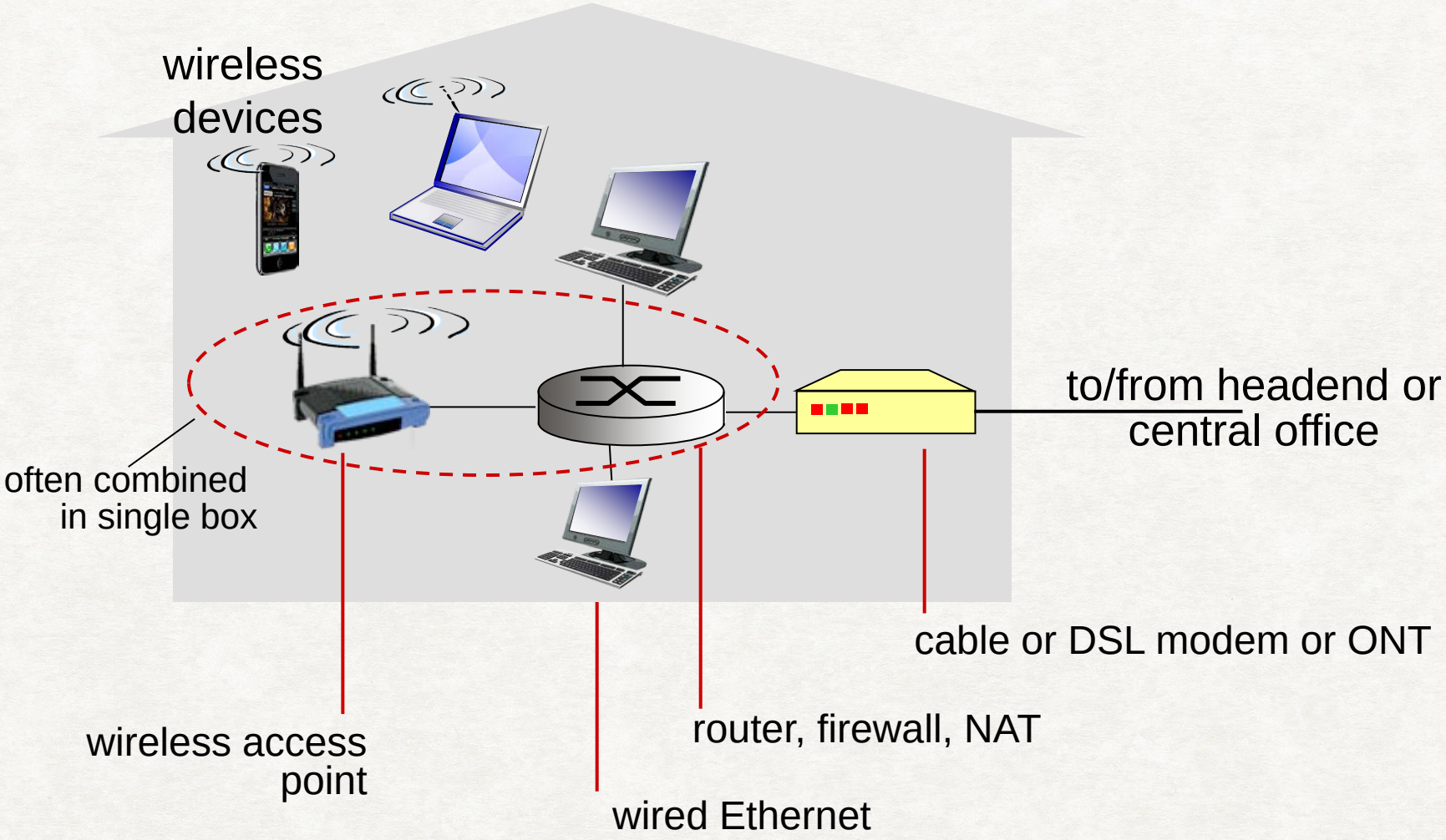
Access net: FTTH



- Fiber-To-The-Home Networks
  - The optical network terminator (ONT) at home is connected by dedicated optical fiber to a neighborhood splitter.
  - The splitter uses a single, shared optical fiber to connect a number of homes to an optical line terminator (OLT) in the telco's CO.
  - FTTH can potentially provide Internet access rates in the gigabits per second range

Reference : *Computer Networking:A Top Down Approach by Kurose & Ross*

Access net: home network



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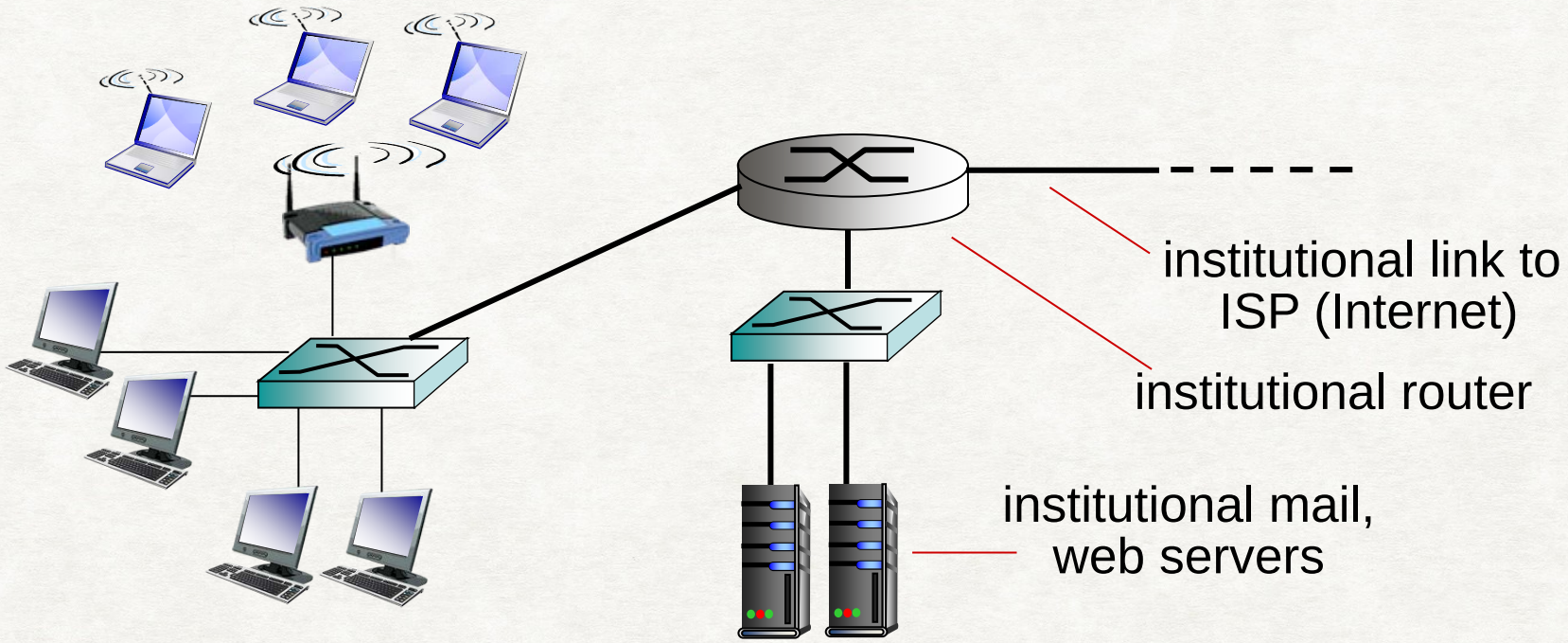
Enterprise access networks : (Ethernet)



Designed as *local area networks* (LAN) with a relatively low number of connected devices.

Typically used to network homes or office buildings

Not really suitable for networks with more than a few hundred computers or for links that need to cover over ~90 m.

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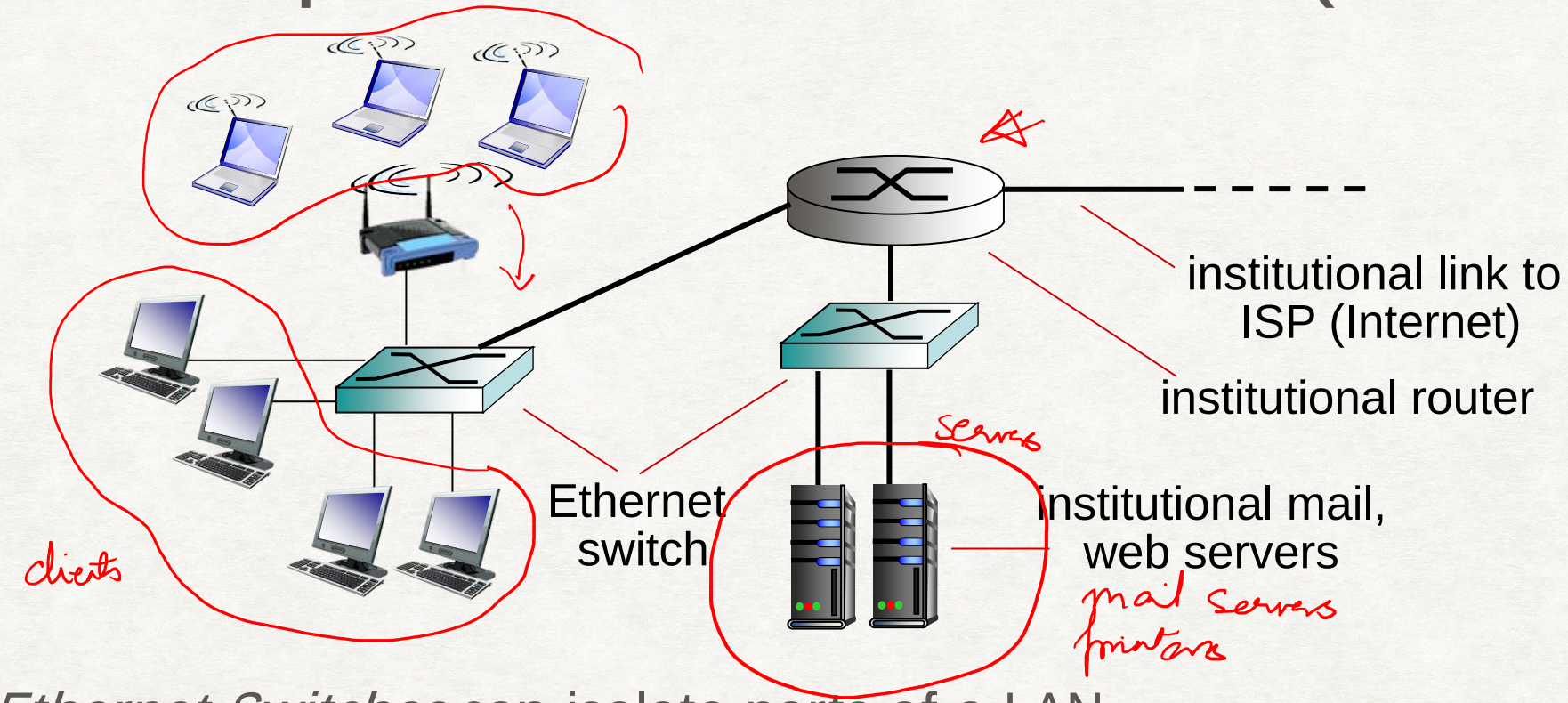
Enterprise access networks : (Ethernet)



Ethernet Switches can isolate parts of a LAN.

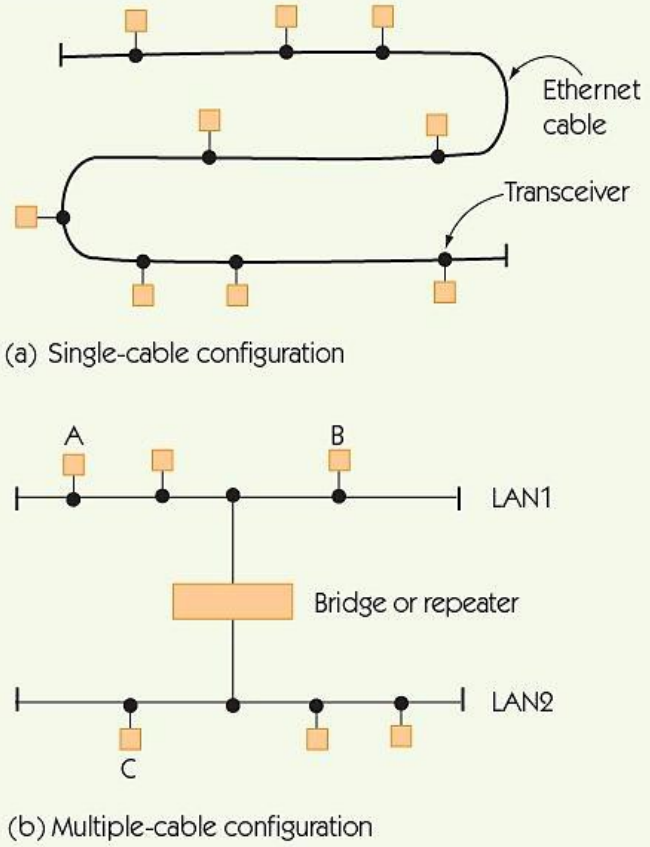
Data rates:

- 10 Mbps (Megabits per second), historic
- 100 Mbps (Fast Ethernet), still in use
- 1000 Mbps ("Gigabit Ethernet" or GbE), most commonly deployed today
- 10 Gbps (10GE, 10GbE, 10 GigE), over 10 years old but still a high end technology

Reference : *Computer Networking: A Top Down Approach by Kurose & Ross*

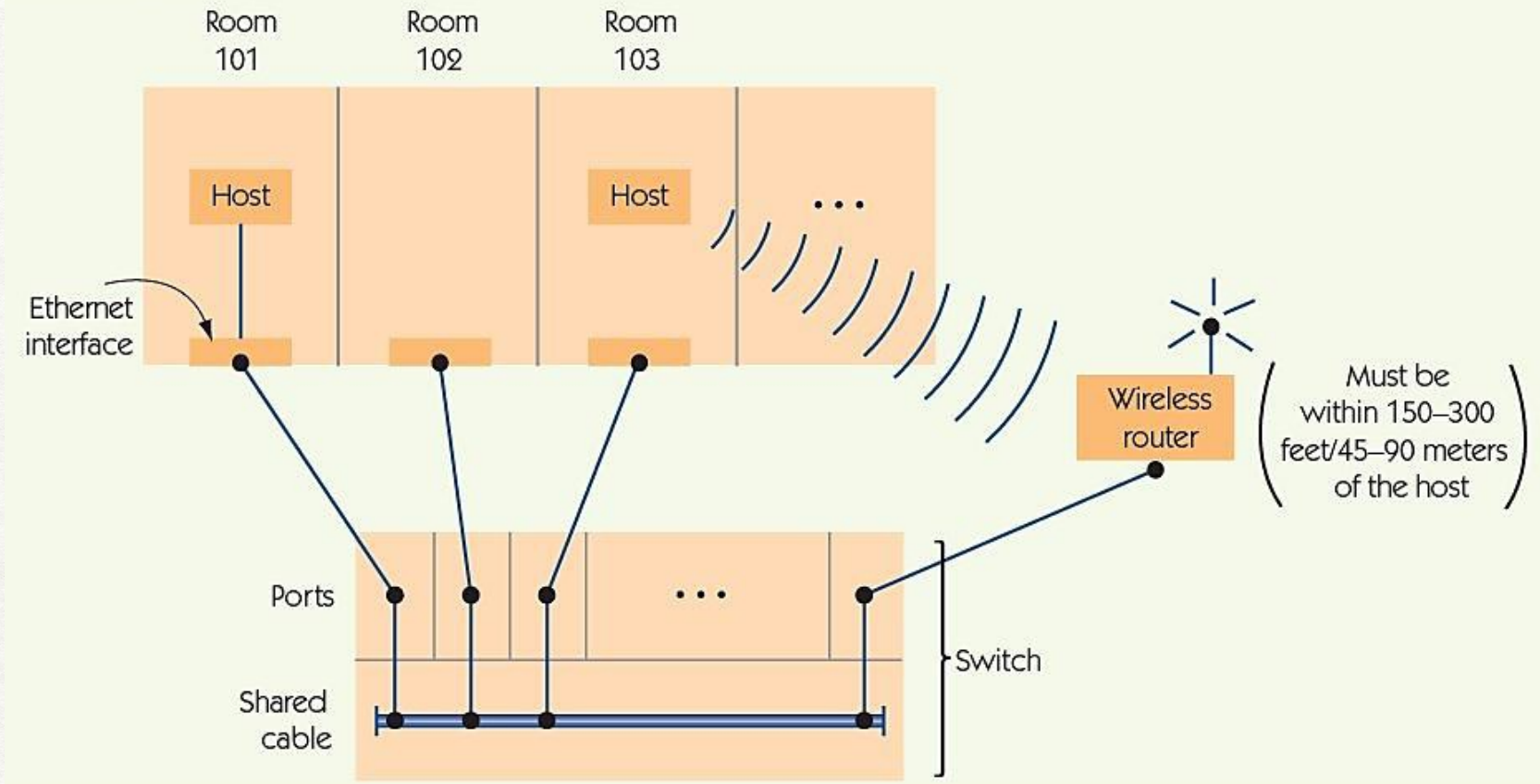
ETHERNET TECHNOLOGY EVOLUTION

FIGURE 7.6



An Ethernet LAN implemented using shared cables

FIGURE 7.7



An Ethernet LAN implemented using a switch

Transmission Speeds

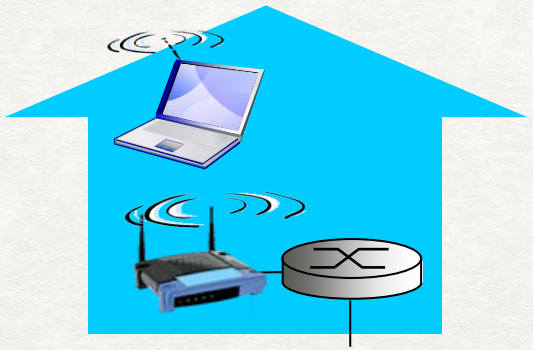
Line Type	Speed	Time to Transmit 8 Million Bits (One Compressed Image)
Dial-up phone line	56Kbps	$8*10^6/56*10^3$ = 142.9 s = 2.4min
DSL line, cable modem	2Mbps	$8*10^6/2*10^6$ = 4s
Ethernet	10 Mbps	$8*10^6/10*10^6$ = 0.8s
Fast Ethernet	100 Mbps	$8*10^6/100*10^6$ = 0.08s
Gigabit Ethernet	1 Gbps	$8*10^6/1000*10^6$ = 0.008s=8ms
10-gigabit Ethernet	10 Gbps	$8*10^6/10*10^9$ = 0.0008s=0.8ms
100-gigabit Ethernet	100 Gbps	$8*10^6/100*10^9$ = 0.00008s=80μs

Wireless access networks

A *wireless* access network connects end system to an edge router via a base station aka an "access point"

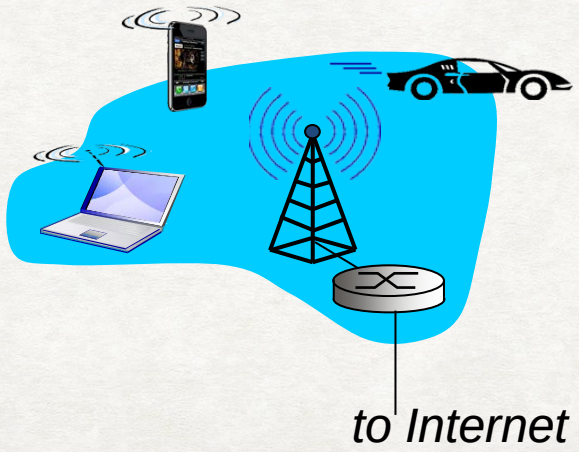
Small-area wireless access

- Wireless LAN (WiFi): IEEE 802.11b/g/n/ac/ax
- within a building (100 ft)
- Data rates vary between 54 Mbps (802.11a) and several Gbps (802.11ac & ax)



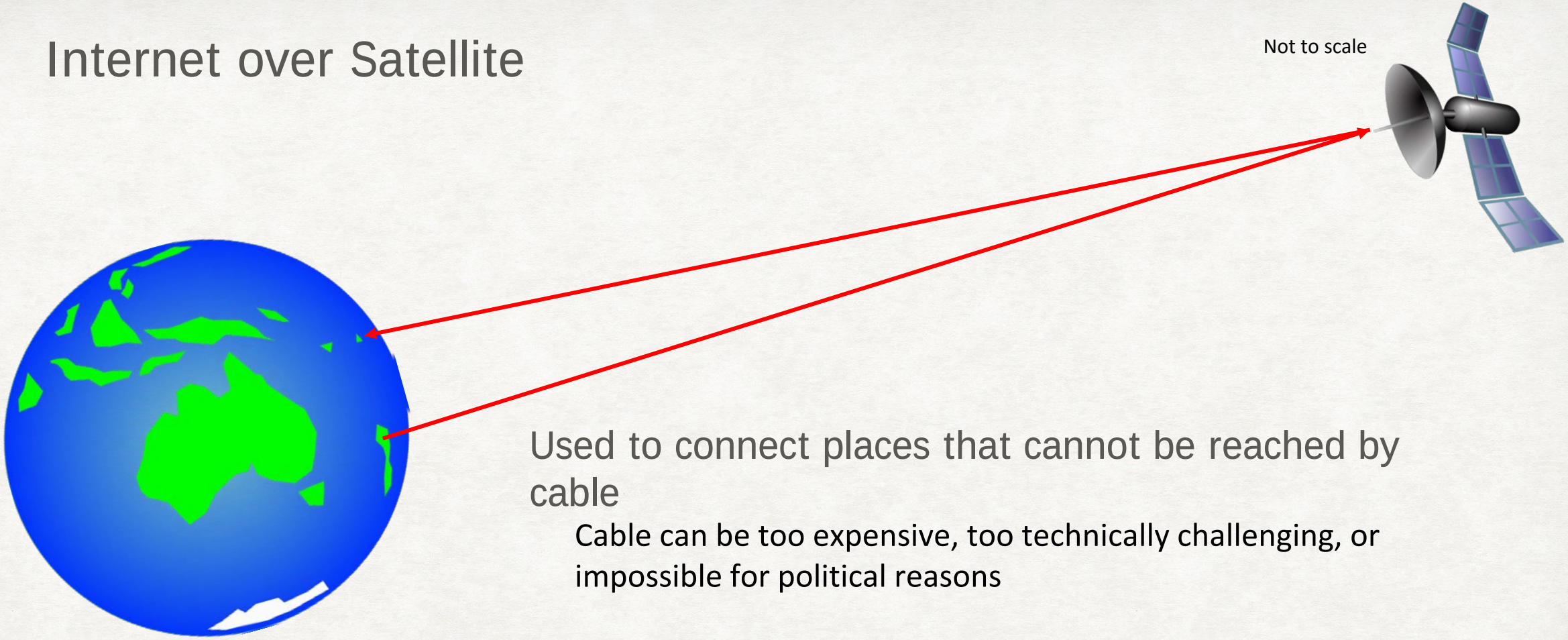
Wide-area wireless access

- provided by a telecom (cellular) operator, 10' s km
- 3G, 4G, 5G mobile
- Data rates vary between 1 and 10 Mbps



Reference : *Computer Networking: A Top Down Approach by Kurose & Ross*

Internet over Satellite



Used to connect places that cannot be reached by cable

- Cable can be too expensive, too technically challenging, or impossible for political reasons

Link goes from ground station on Internet side via satellite to ground station of local network or ISP

Entry cost is low but operating cost is high

- Typically > ~US$200/Mbps/month

Geostationary satellites

- Satellite orbits at the same angular velocity as the earth's spin, so appears to be in a fixed spot as seen from the ground stations.
  - Geostationary orbit (orbital altitude) is 35,786 km above the equator
- High latency: Signals take around 0.25 seconds to get to the satellite and back
- Can use fixed antennas but must be big in size.
  - Received signal power drops by square of distance: low signals at the ground stations.
- Until a few years ago, all Internet connectivity in remote places used geostationary satellites

Satellites: Medium (MEO) and Low Earth Orbit (LEO)

O3b MEO antennas – view from back showing the motors that move the antenna

MEO: Orbital altitude typically several 1000 km

Example: O3b (SES): 8000 km
Need tracking antennas (movable), but can be much smaller than GEO
Need minimum of 2 antennas per ground station
Need a minimum of 4 satellites (ideally more)
Much lower latency + higher bit rates

SpaceX : Starlink , Amazon

LEO: Orbital altitude between 200 and 1000 km

- No need for tracking antennas
- Need dozens to hundreds or even thousands of (small) satellites
- Even lower latencies and much higher bit rates
- But: routing and regulatory issues present challenges

Physical media

The medium that transmits a bit between the transmitter and the receiver

Guided media:

signals propagate in solid media: copper, fiber, coax

Unguided media:

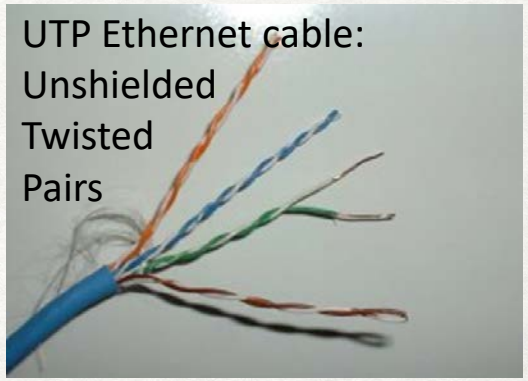
signals propagate freely, e.g., radio

1. Twisted Pair (TP)

Two insulated copper wires.

Category 5: 100 Mbps, 1 Gpbs Ethernet

Category 6: 10Gbps



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Physical media

The medium that transmits a bit between the transmitter and the receiver

Guided media:

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Unguided media:

signals propagate freely, e.g., radio

2. Coaxial cable:

Two concentric copper conductors

broadband:

multiple channels on cable

HFC

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Physical media

The medium that transmits a bit between the transmitter and the receiver

Guided media:

signals propagate in solid media: copper, fiber, coax

Unguided media:

signals propagate freely, e.g., radio

3. Fiber Optic Cable:

- Glass fiber carrying light pulses, each pulse a bit
- High-speed point-to-point transmission (e.g., 10's-100's Gbps transmission rate)
- Low error rate:
- Repeaters spaced far apart
- Immune to electromagnetic noise

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Uses of Fibres

Uses

- LANs
- Access networks (fibre to the home)
- Wide area networks (backbone)
- International connections (submarine fibre cables)

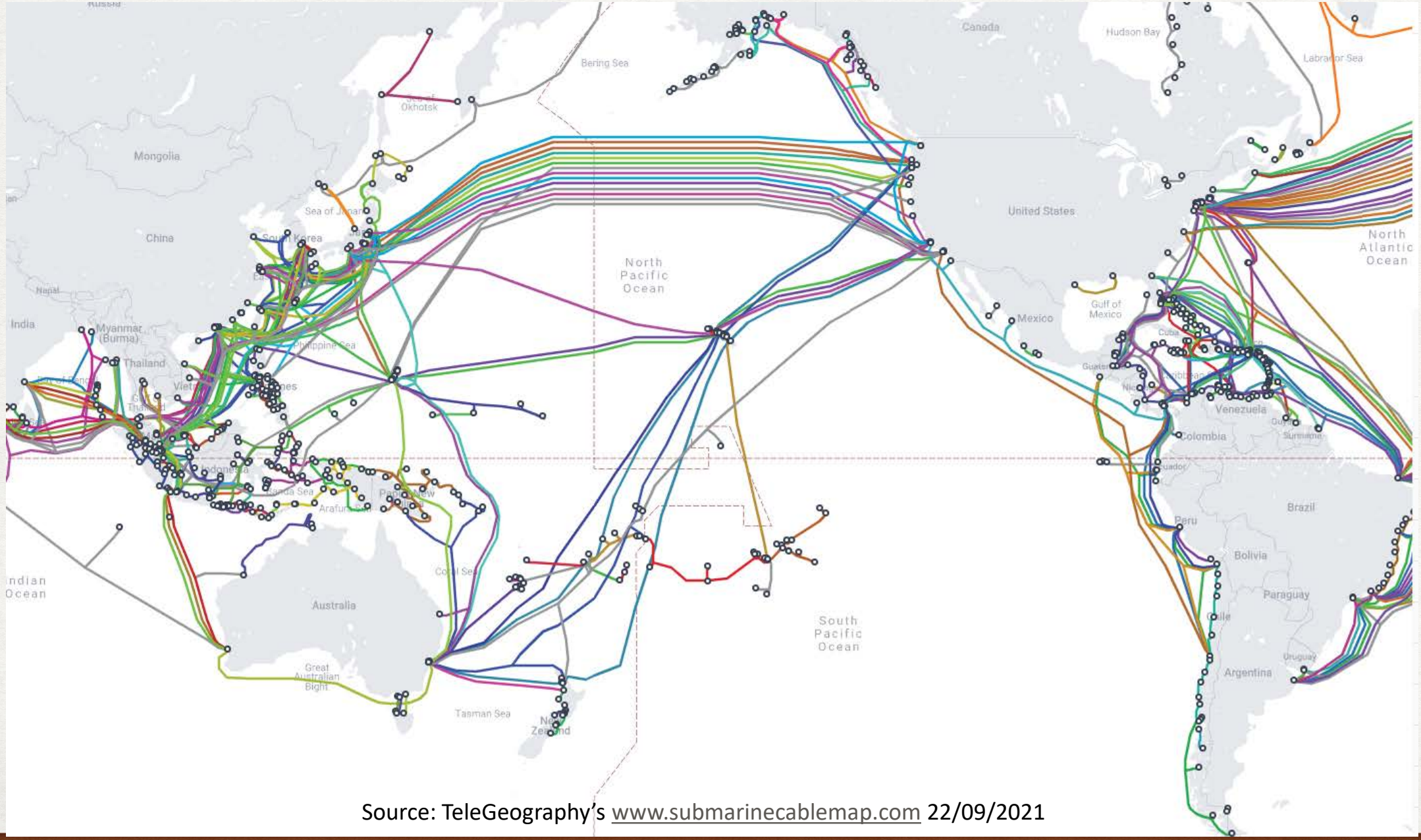
Advantages

- Very high data rates
- Cheap (at least the fibre itself)
- Hard to eavesdrop on

Drawbacks:

- More difficult to install and repair (splicing) than twisted pair cable
- Mechanically weak - requires a protective pipe or even a mechanical cable to take strain

Optical Fibre Submarine Cables



Source: TeleGeography's www.submarinecablemap.com 22/09/2021

Physical media

The medium that transmits a bit between the transmitter and the receiver

1. Guided media (“Wired”)
   Signals propagate in solid media: copper, fiber, coax

2. Unguided media (“Wireless”)
   Signal carried in electromagnetic spectrum
   e.g., radio
   no physical “wire”
   propagation environment effects:
   - reflection
   - obstruction by objects
   - interference

- Terrestrial microwave
  - e.g. up to 45 Mbps channels
- LAN (e.g., WiFi)
  - 11Mbps, 54 Mbps
- Wide-area (e.g., cellular)
  - 3G cellular: ~ few Mbps
- Satellite
  - Kbps to 45Mbps channel
  - 270 msec end-end delay

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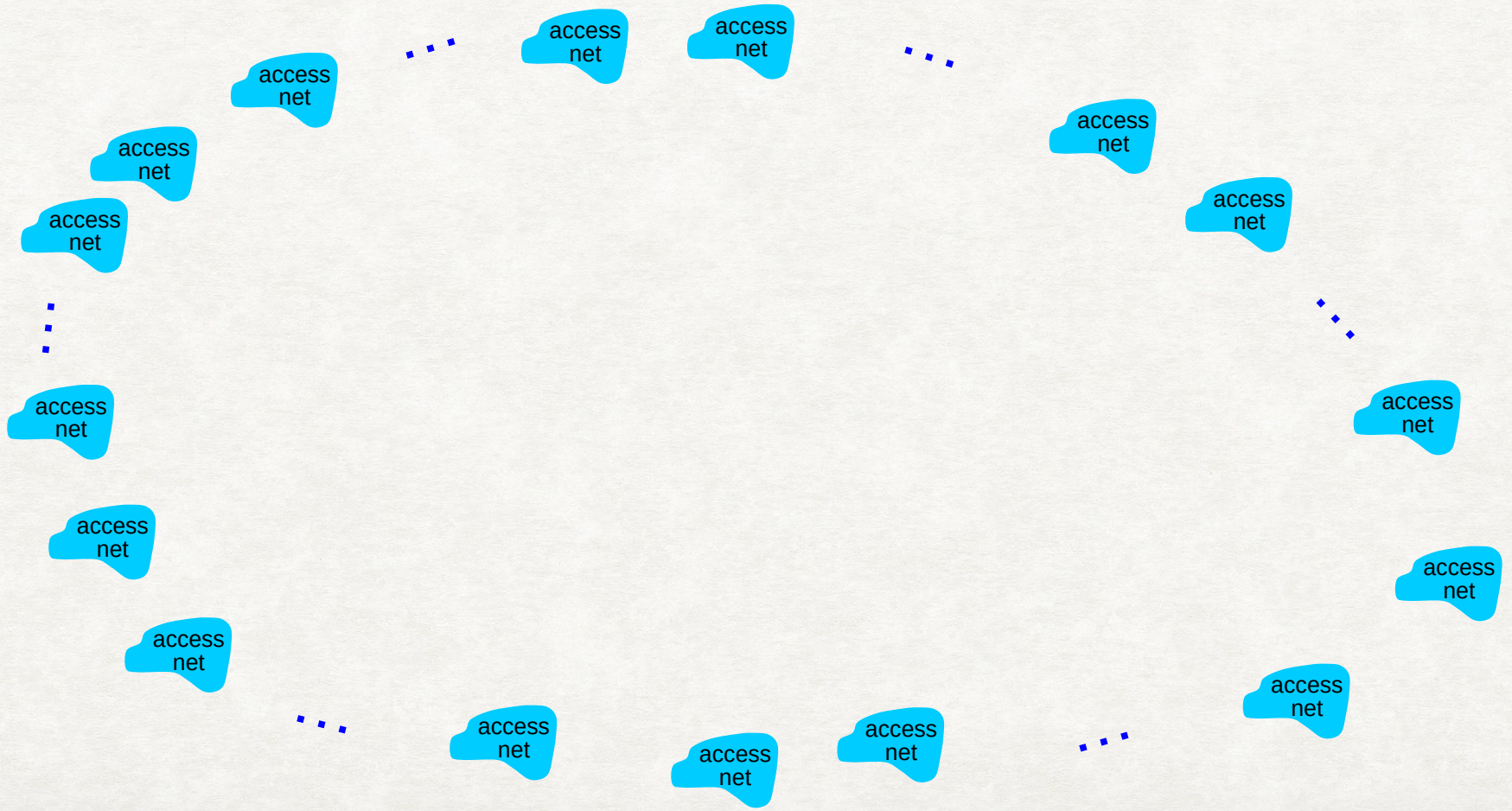
Internet structure: network of networks

Question: given *millions* of access ISPs, how to connect them together?



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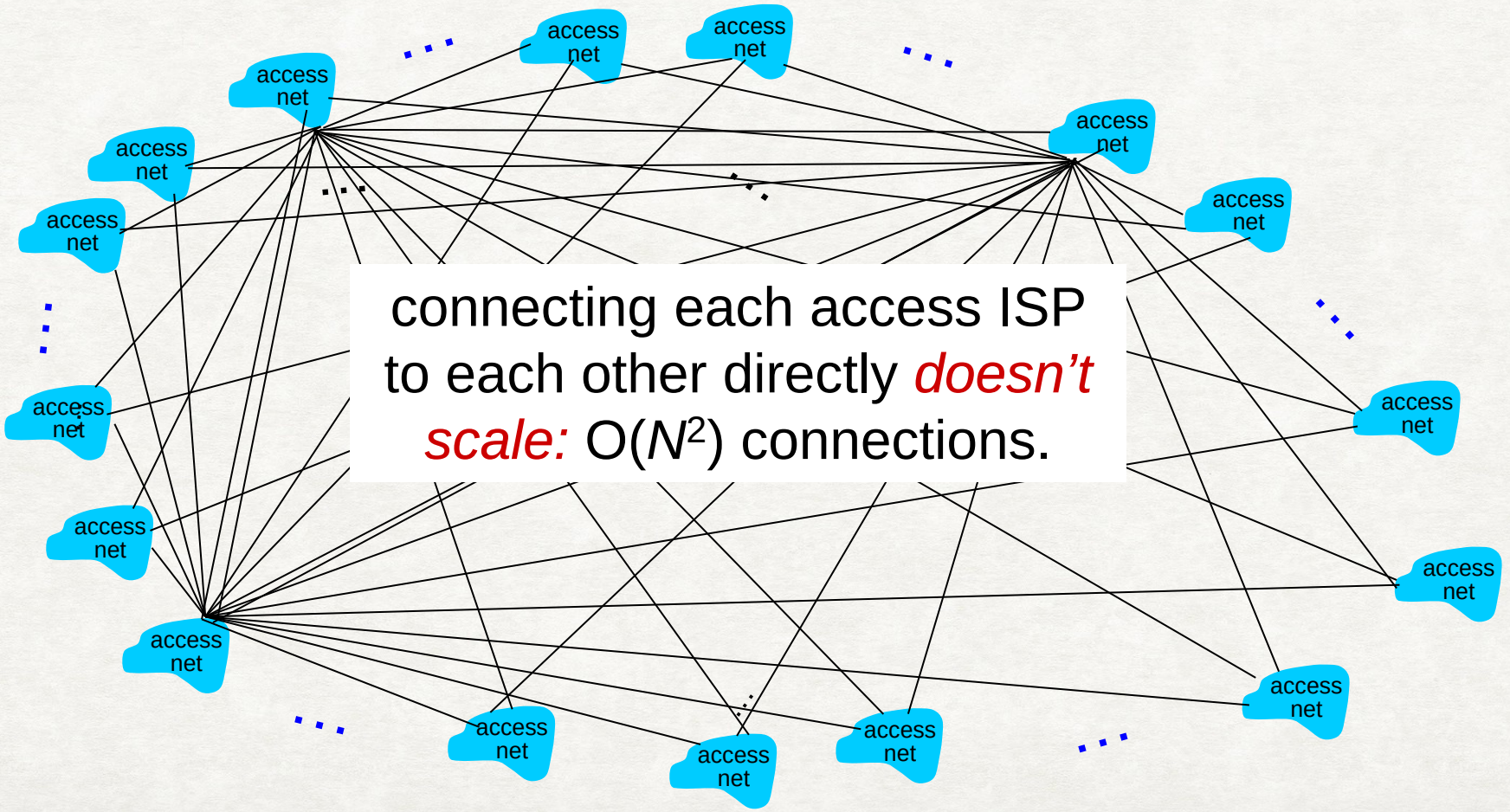
Internet structure: network of networks

Option: connect each access ISP to every other access ISP?



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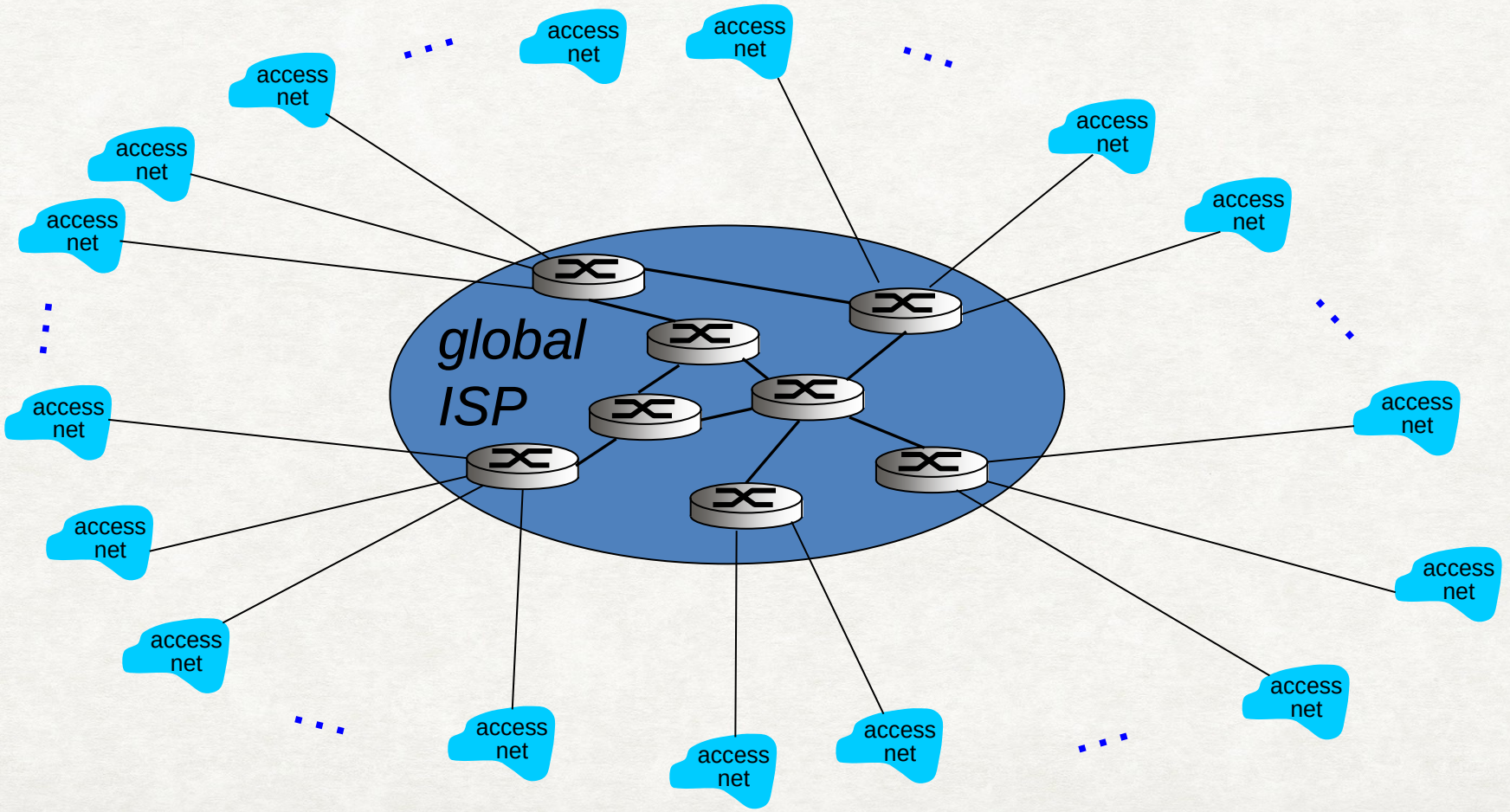
Internet structure: network of networks

Option: connect each access ISP to a global transit ISP? Customer and provider ISPs have economic agreement.



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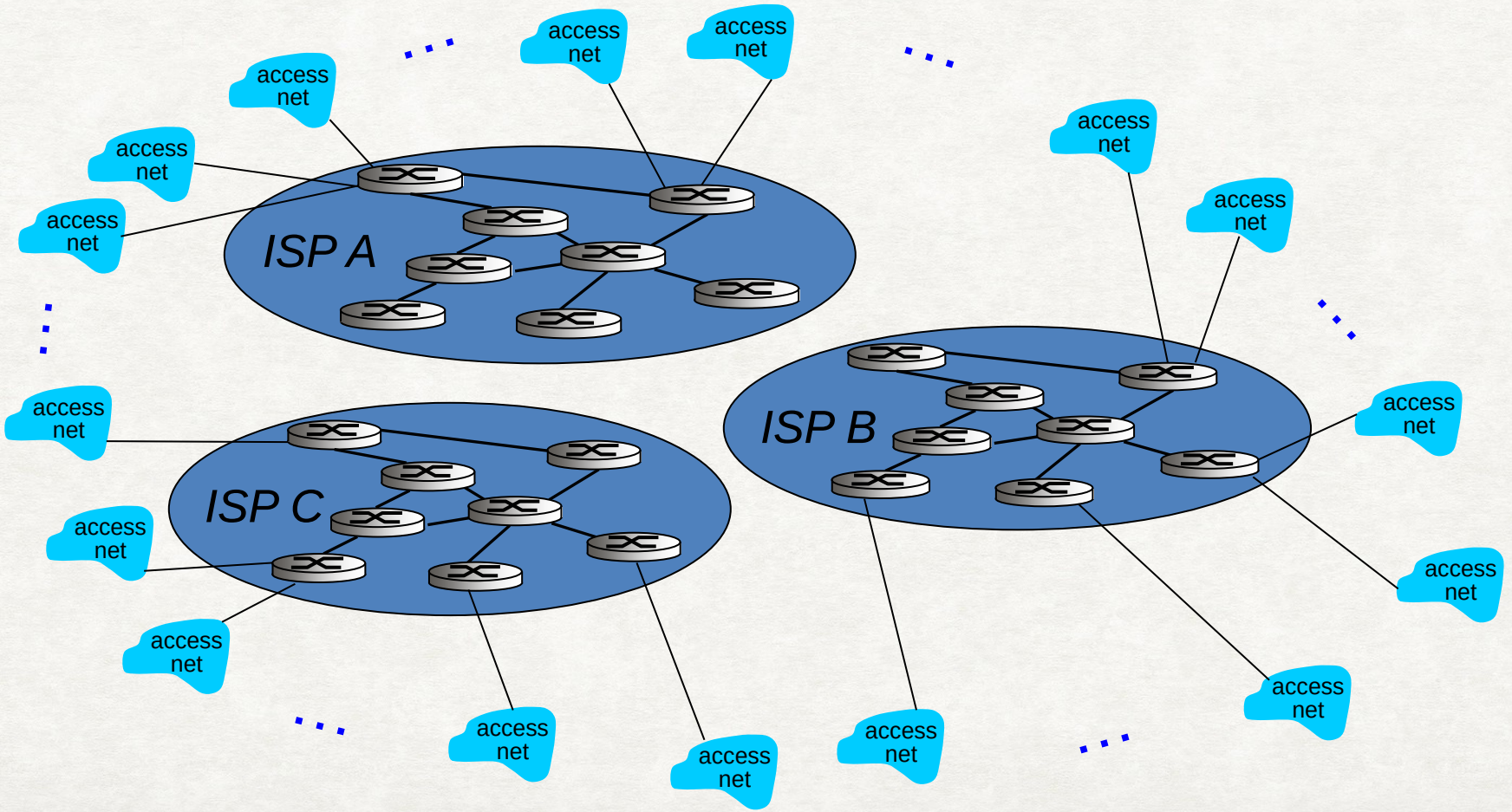
Internet structure: network of networks

But if one global ISP is viable business, there will be competitors ….



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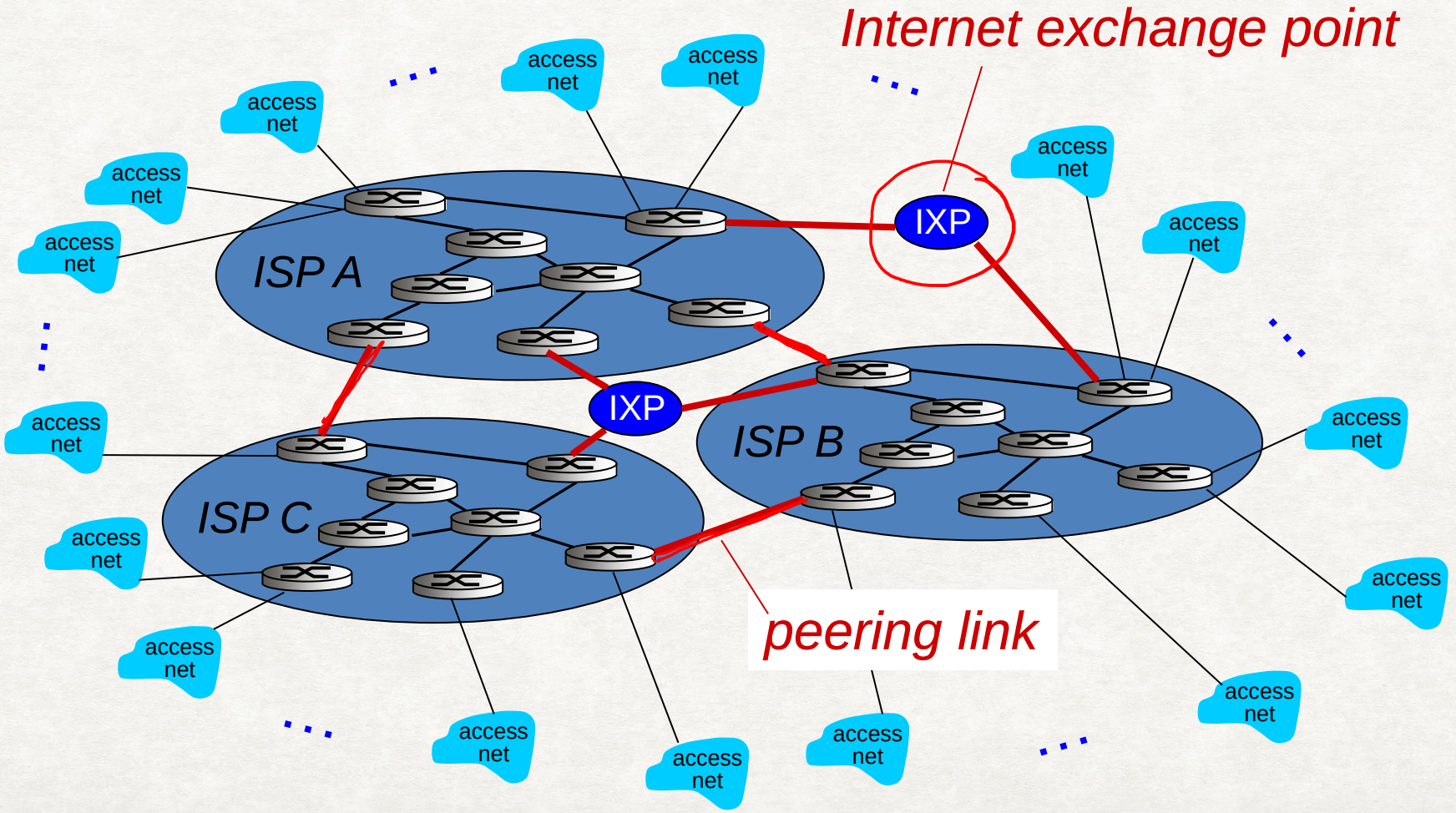
Internet structure: network of networks

But if one global ISP is viable business, there will be competitors …. which must be interconnected



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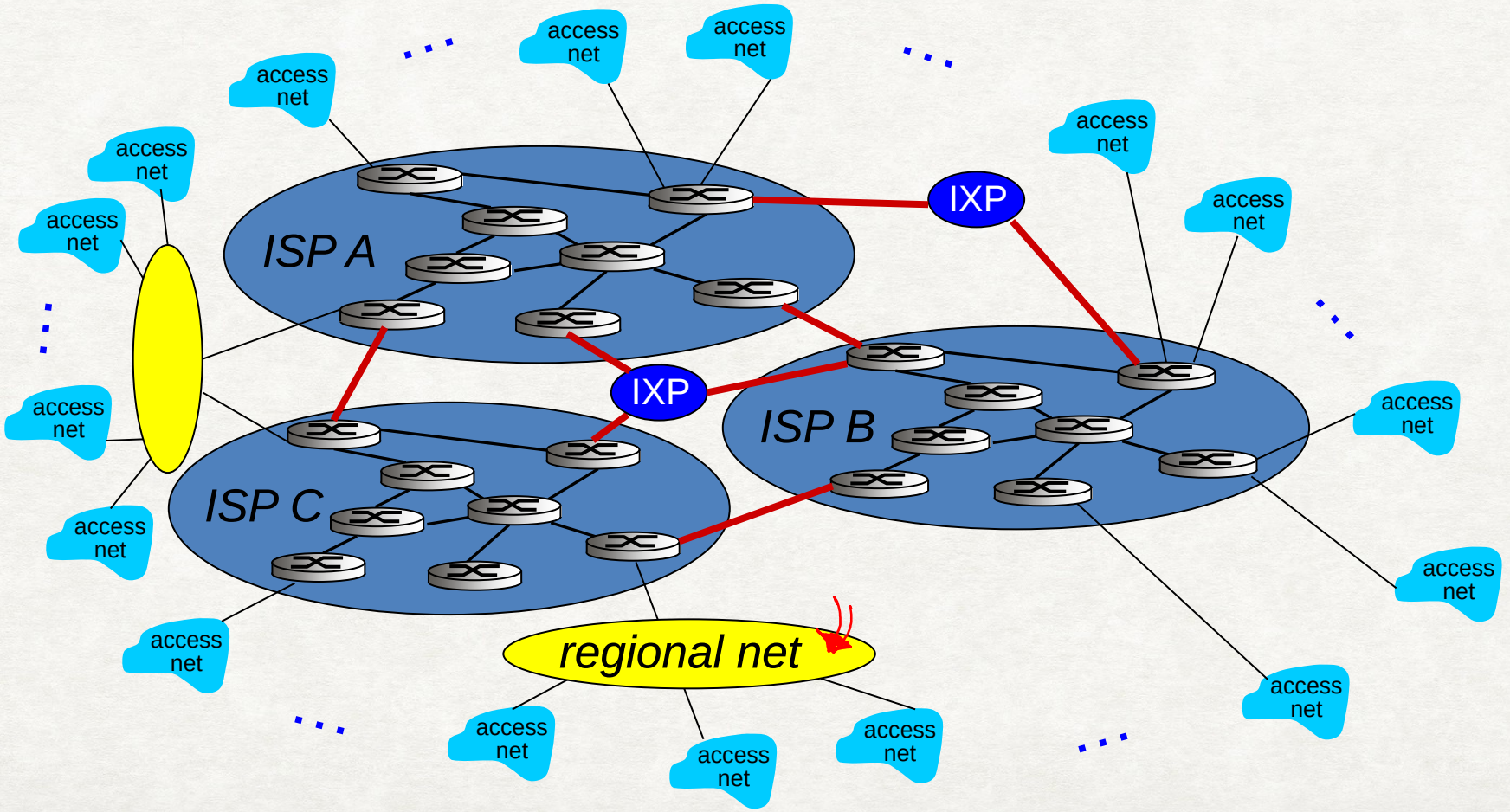
Internet structure: network of networks

… and regional networks may arise to connect access nets to ISPS



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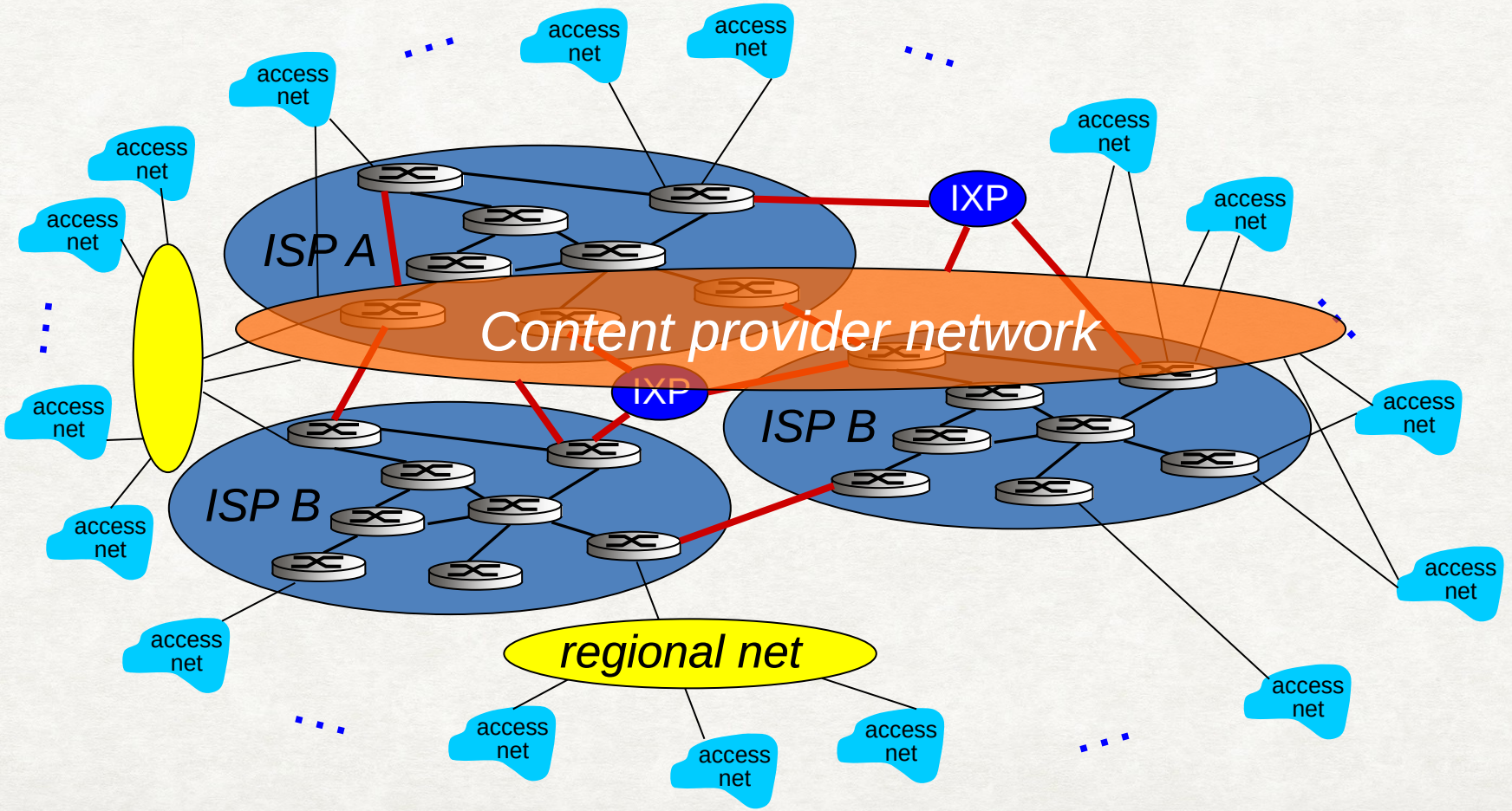
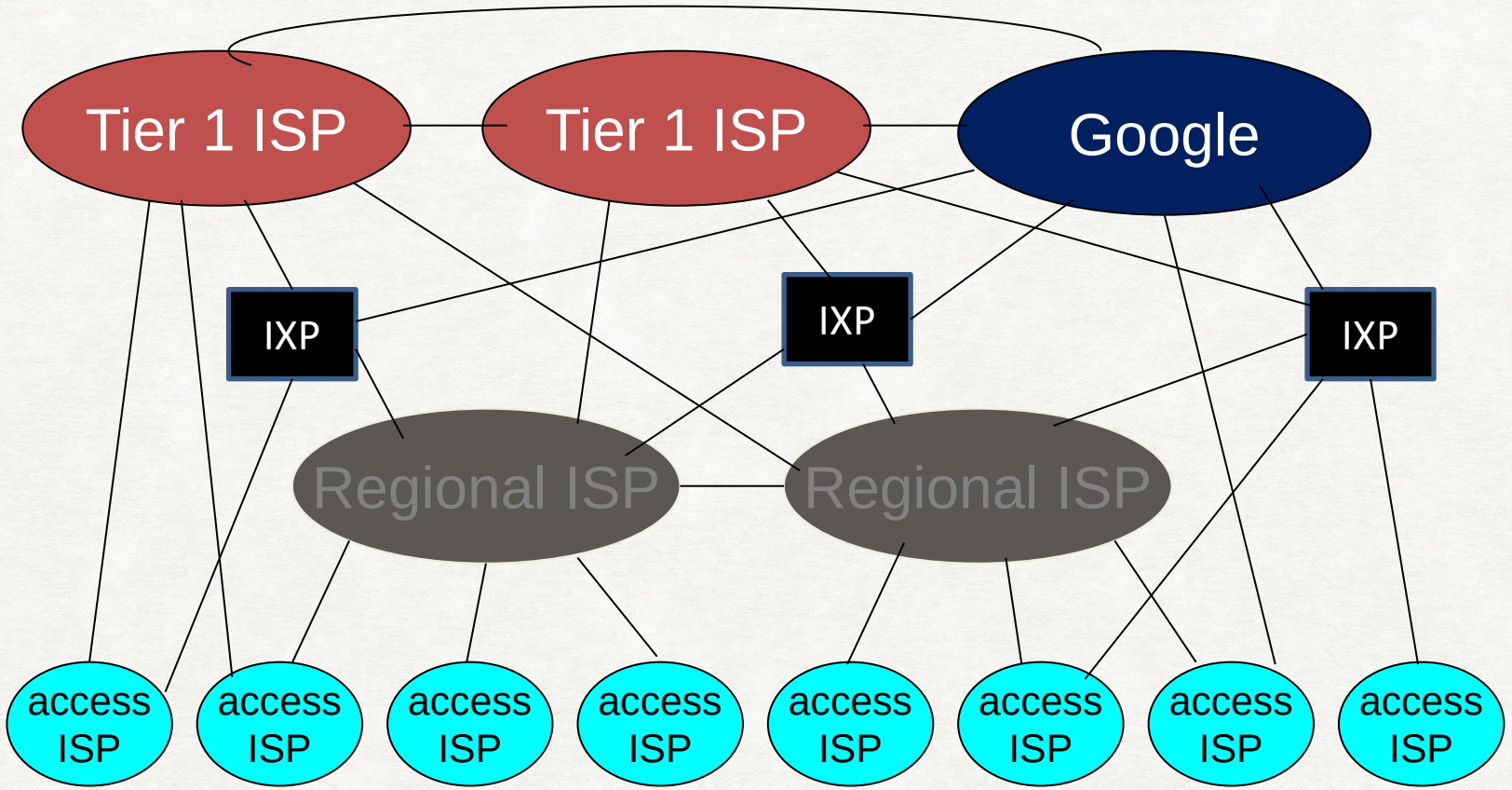
Internet structure: network of networks

… and content provider networks (e.g., Google, Microsoft, Akamai) may run their own network, to bring services, content close to end users



Internet structure: network of networks



Tier-1 commercial ISPs (e.g., Verizon, Sprint, AT&T, NTT), national & international coverage

Content provider network (e.g, Google): private network that connects its data centers to Internet, often bypassing tier-1, regional ISPs

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